The Use of Computers in Population-Based Diabetes Management

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Type 2 diabetes mellitus affects almost 10% of the U.S. adult population, and its prevalence is increasing [1,2]. The risk of heart disease and stroke is 2 to 4 times greater in patients with diabetes, and these patients are also at increased risk of renal disease, blindness, and lower extremity amputation [3–5]. Numerous large, well-conducted randomized trials have demonstrated that these complications can be reduced or prevented with appropriate medical care [6–14]. Despite the widespread publication of evidence-based practice guidelines, however, care of patients with diabetes remains far from ideal. Community-based observational studies have repeatedly shown poor rates of glycemic, blood pressure, and cholesterol control in patients with diabetes [15–23].

The care of a patient with diabetes is complex. Patients must be seen in clinic several times per year for testing of risk factor levels (such as glycosylated hemoglobin [HbA_{1c}] and low-density lipoprotein cholesterol), assessment of blood pressure and foot care, and adjustment of medical regimens [24]. Patients are often taking 5 or more medicines to treat hyperglycemia, hypertension, and hyperlipidemia. Many patients also have other associated comorbidities such as coronary artery or peripheral vascular disease, depression, and obesity. Currently, the majority of diabetic patients are cared for by primary care physicians who also arrange for consultation with ophthalmologists, nutritionists, podiatrists, and other health care professionals.

It is perhaps not surprising that, in contrast to the care provided in the unique environment of randomized clinical trials, care in the community often fails to achieve evidence-based goals. Given the proven efficacy of appropriately adjusted pharmaceutical therapy, limitations in observed effectiveness of care can be attributed to failures at any number of steps in care. These limitations include lack of identification or loss to follow-up of patients with diabetes, clinical inertia in the adjustment of pharmaceutical therapy, lack of provider awareness of evidence-based guidelines, and patient-centered factors related to appointment or medication adherence and to lifestyle modification [25–30]. Barriers related to cost of care, convenience and accessibility to clinical sites, and misunderstandings about prescribed regimens also reduce overall effectiveness of care [31–34].

A Population-Based Approach

Chronic disease management has traditionally been physician-centered, with changes in care organized around the clinical visit. This model puts pressure on providers to address all aspects of clinical management in the setting of extreme time constraints. Moreover, the very occurrence of these clinic visits—and thus opportunities for adjusting care to meet evidence-based guidelines—depends both on physician appointment availability and on patient participation and active engagement in the process of care. In contrast to traditional clinic-based care, population-based diabetes management takes an epidemiologic overview to plan, organize, deliver, and monitor patient care [35]. Key elements of population-based care include a community perspective, application of clinical epidemiology principles, evidence-based practice, an emphasis on outcomes, and an emphasis on prevention [36]. The organization of clinical data for a large cohort of patients is critical to the population-based approach. The collection, storage, and evaluation of these data are particularly well-suited to computerized clinical information systems. Indeed, the effective integration of information technology ("informatics") should be seen as a prerequisite for the overall improvement of diabetes care.

Computerized information systems are finding increasing use in clinical care. These informatics systems are used to (1) create patient registries by identifying specific populations (such as the cohort of all type 2 diabetic patients in a particular medical practice); (2) identify patients within the registry who are not meeting particular goals (eg, testing frequency, risk factor levels, specialty referrals); (3) coordinate specific interventions (such as patient mailings or physician reminders); (4) provide evidence-based treatment algorithms to aid in clinical decision making; and (5) serve as the organizing structure for integrated care delivery. Below we review some examples of how computer informatics systems have been applied to diabetes management and describe both the strengths and limitations of these approaches.

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Diabetes Patient Registries

The first step in population-based disease management is to identify a specific population of patients to be managed. Population management requires that the care delivery system be responsible for a particular group of patients and, correspondingly, that these patients receive care primarily from this medical system. Managed care organizations by their nature have been at the forefront of creating registries of specific patient populations. Engelgau et al, for example, describe their experience in developing a diabetes surveillance system for a group of 3 managed care organizations. Combining data from inpatient, pharmacy, clinic, and laboratory records, they sought to develop an algorithm to characterize their diabetic populations [37].

Important barriers to retroactively defining a patient population include shortcomings in chart documentation, inaccuracies in data sources created for other purposes (such as billing claims), and difficulties in linking data from different sources [38]. Prospective enrollment of patients by clinicians is a more accurate approach but is limited by low rates of physician participation [39].

Assessing and Improving Quality of Care

Once established, population-based diabetes registries are used to characterize and subsequently improve the quality of care within a medical system. Various algorithms have been developed using prediction rules to identify high-risk subgroups of patients in need of more intensive interventions [40,41]. The advent of new informatics technologies provides the potential for efficient identification of population subsets by any number of relevant criteria ("red flags"), such as high number of prescribed medicines, elevated blood pressure level, or prespecified adherence barriers. This "surveillance function" identifies patients and/or responsible physicians who can then be targeted for tailored interventions [42].

There have been a number of different strategies employed to improve the overall quality of care for patient populations [43,44]. Interventions directed toward physicians have included reminders and evaluations or "report cards" [45]. Computer-generated reminders can be patient-specific or general, and can be in the form of letters, e-mail messages, or on-screen prompts for systems with computerized medical records [46]. Report-card–style evaluations feed back a physician's performance on various criteria for the patients identified as being under his or her care [47]. Alternately, reminders can be directed toward patients, generally as letters (on clinic letterhead) to encourage appointment adherence or to recommend laboratory testing [48,49].

Hurwitz et al found that a computerized reminder system was effective in improving quality of diabetes care. In a randomized controlled trial with 181 patients, the authors found that testing frequency (for HbA_{1c}, glucose, and albuminuria) and ophthalmology referrals were significantly greater in the reminder group [48]. In a large meta-analysis of computerized prompts for preventive care services (not limited to diabetes care), Balas et al also found that such prompting significantly improved physician performance [50]. Other research has found that computerized prompts that require physician responses are more effective compared to passive reminders [51].

Computer-Based Decision Support Systems

Building on the technology of simple reminders, clinical informatics systems can now provide real-time evidence-based decision support for providers during patient encounters. Computer-based decision support systems (CDSSs) can lead to improved care by interacting with health care providers to modify diagnostic and therapeutic decisions. Approaches include (1) automated alerts to providers in response to the appearance of certain types of abnormal clinical data, (2) programs that critique new orders and propose changes in those orders when appropriate, (3) programs that suggest new orders and procedures in response to relevant patient data, and (4) applications that function by summarizing patient care data and that attempt to retrospectively assess the average or typical quality of medical decisions and therapeutic interventions made by health care providers [52].

In developing computer-based decision support tools, evidence from clinical trials and meta-analyses is combined with provider consensus to define diagnostic criteria, therapeutic goals, and algorithms for intensifying treatment [53]. There is ongoing enthusiasm for implementing such interventions via computer-based approaches [54–56]. Several diabetes management programs have been shown to lower HbA_{1c} levels, reduce foot amputations, and potentially save money over time [57,58]. However, new programs must be tested in randomized trials to control for temporal trends in care and must look at important clinical outcomes rather than just process measures. For example, Hetlevik et al found that a computer-based clinical decision support system implemented in 29 health centers caring for more than 1000 diabetes patients did not lead to clinically significant changes in physician behavior or in patient outcomes [59]. Our own experience with computer-based decision support, also tested in a randomized controlled trial, found that rates of testing and screening significantly increased while actual risk factor levels showed small but nonsignificant improvements after 1 year [60].

In another controlled study, Lobach et al demonstrated that provider-oriented, patient-specific computer-based decision support used at the time of the clinical encounter improved process outcomes but not disease outcomes in diabetes [61]. In their review of trials of clinical decision support

systems (not limited to diabetes care), Hunt et al concluded that published studies of CDSSs are increasing rapidly, and their quality is improving [62]. CDSSs can enhance clinical performance for drug dosing, preventive care, and other aspects of medical care, but not convincingly for diagnosis. Thus, although CDSSs represent a very promising tool for improving the care of diabetic populations, more randomized trials focusing on patient outcomes are needed.

Extending Disease Management Beyond the Clinic Visit

One of the goals of a population-based approach to diabetes care is to manage the health of a cohort of patients without relying exclusively on the clinical encounter to make changes or otherwise manage the disease. Computer-based algorithms allow a greater role for nonphysicians in the participation of population-based care.

The specific benefits of computer aids to population-based diabetes care are gradually becoming rigorously documented. In a controlled trial, Peters and Davidson showed that a comprehensive diabetes care program that included nurses using a computerized tracking system and evidence-based management protocols led to significant improvements in glycemic and cholesterol control and in several process measures of quality diabetes care [63]. Over 2 years, intervention patients received more frequent screening for diabetes complications and had a decrease in HbA_{1c} levels (from 11.9% to 8.8%) compared with usual care patients, who had no change in HbA_{1c} levels.

Aubert et al report the first randomized trial of a primary care–based case management program for diabetic patients [64]. The intervention achieved significant reductions in HbA_{1c} values and improvements in self-reported health. Working within a group-model health maintenance organization (HMO), nurse case managers enrolled patients in an education program, arranged for diet and exercise counseling, and managed glycemia using an algorithm under the direction of an endocrinologist and family physician. After 2 initial assessments the nurse saw patients quarterly, with weekly phone contact for those on insulin. Patients were otherwise followed by their primary care providers. Of 138 diabetes patients (121 with type 2 diabetes mellitus), 71 were randomized to the intervention, and 72% completed 12-month follow-up. HbA_{1c} levels decreased more in the intervention group (1.7% versus 0.6% in the usual care group; $P < 0.001$) and this group had a greater improvement in self-reported health status. This study also demonstrates that diabetes care can be substantially improved by enhancing primary care, not bypassing it. Using personnel and resources already available within a HMO, they created comprehensive system change capable of substantially improving key clinical outcomes [65].

Vaughan et al implemented and evaluated a CDSS for nurse-managed oral hypoglycemic therapy in type 2 diabetes [66]. Using computer-based treatment algorithms, a nurse provided exclusive management of 102 patients with newly diagnosed type 2 diabetes. After an initial education, patients were seen at their usual clinic by the nurse only on a monthly basis until satisfactory glycemic control was established and thereafter reviewed every 3 months. Patients in the control group of practices ($n = 116$) were treated according to normal procedures. In the study group, 98% patients achieved HbA_{1c} levels within the normal range. The control practices achieved much poorer degrees of metabolic control ($P < 0.01$). This decision support system was successful at achieving standards of diabetes control and care equal to or better than conventional structures of diabetes care. Thus, implementation of such a system on a simple computer platform could greatly assist and possibly improve diabetes management in general practice.

One limitation of intensive nurse case management is the potential cost inefficiency—in the Aubert study [64], it took a case manager 1 year to lower HbA_{1c} levels from 9.0% to 7.3% in 71 patients. Another, potentially less expensive application of informatics systems in population management is automated processes such as telemedicine. In randomized trials, Piette et al have shown that automated calls with telephone nurse follow-up led to improvements in process outcomes and improved HbA_{1c} levels [67,68]. A recent Cochrane organized review of the telemedicine literature found only 5 trials assessing the provision of home-based care for chronic disease. Most studies were of small numbers of patients, and none showed clear benefits [69]. Further research is clearly needed in this area.

Integrated Models of Care

Integrated models of care take a population-based perspective and fully apply informatics resources for comprehensive diabetes management. Such approaches provide more meaningful visits for diabetic patients and more intensive follow-up, ensure closer adherence to evidence-based guidelines, meet the self-management needs of patients, and ensure ready availability of meaningful clinical information on individual patients and the larger population of patients [65].

Several HMO-based primary care disease management programs have effectively improved diabetes care. The disease management program at Group Health Cooperative of Puget Sound integrates diabetes-specific information into an electronic medical record, provides diabetes-specific intervention prompts, facilitates patient scheduling to arrange needed services, restructures visits to focus on the patient's diabetes (rather than other acute problems), and offers organized care by a range of providers (primary care providers, endocrinologists, dietitians, and diabetes educators). Two

years after implementation of this program, annual rates of HbA_{1c} measurement increased slightly (from 77% to 80%), retinal examinations increased from 46% to 64%, and foot examinations increased from 18% to 56%. In the year after it was made available, 80% of physicians had logged on to the diabetes registry. The authors concluded that providing support to primary care teams in several key areas has made a population-based approach to diabetes care a practical reality in the setting of a staff model HMO [70].

Other HMO-based systems have taken a similar approach [71]. In New Mexico, the Lovelace Health Systems' EPISODES OF CARE program resulted in improved control through the integration of practice guidelines, physician performance feedback, increased patient education and clinic access, and a computerized reminder system. This cohort study found that after 2 years, 78% of patients had had at least 1 HbA_{1c} test, the mean value decreased from 12.2% at baseline to 10.4%, and eye examination rates increased from 47% to 53% [72]. Results from the Kaiser Health Plan are also encouraging. Preliminary data show improved metabolic control as well as potential cost-savings due to reduced rates of hospitalization in intervention patients [73]. Although HMO disease management programs are limited in their transportability outside of HMO settings, they do provide guidance for development of more generalizable programs.

Future Directions: The Role of Internet Access and Collaborative Medical Records

Increasing patients' access to their own electronic medical records represents a new frontier in diabetes management. Web-based informatics programs create the potential to provide individuals with secure and convenient access to their personal medical information [74]. In an ongoing survey of internet use, the Pew Internet & American Life Project has found that the majority of Americans have internet access, and among those with access, 55% have used the internet to obtain health information, citing convenience and anonymity. Many physicians and health care organizations have either started to interact electronically with patients or plan to do so [75]. In a recent survey, 14% of physicians report communicating with patients via e-mail [76]. The impact on patient-physician collaboration of this increased access is not yet known, although older studies of patient-carried "paper records" showed that use of such records improved the effectiveness of chronic disease care [77,78]. A large randomized trial of diabetic patients' use of a home medical record is currently underway [79].

The internet offers availability 24 hours a day, low cost, and the capacity to reach large numbers of patients and thus represents a promising method of delivering diabetes self-management programs. Web sites that emphasize personalized goal setting, feedback, and social support have been met with high levels of acceptance and patient satisfaction [80,81]. In one pilot study, patients who frequently accessed a Web site designed to increase physical activity through goal setting, peer support, and an online "personal coach" had increased physical activity and a decrease in depression symptoms [82]. Another study found that a professionally moderated internet discussion group for patients with diabetes was widely used and appeared to be a useful strategy for engaging patients in chronic disease care [83].

Another new approach uses computer-based, self-administered diabetes care questionnaires that can be entered directly into the electronic medical record. In one pilot project, patients completed a questionnaire using a touchscreen interface, and their responses were then matched to evidence-based guidelines to provide patient-specific diabetes care advice. The average time required was 10.9 minutes, and a mean of 3.0 recommendations were provided per patient. Patient and health care practitioner satisfaction with the questionnaire and the patient-specific feedback was high [84]. Such an approach promises to improve both the patient clinical database as well as patient-physician collaboration.

Caveats and Limitations

Use of computers in population-based diabetes management is driven by evidence-based guidelines for care. However, it is important to note limitations of these and other quality benchmarks. In a review of evidence-based guidelines in diabetes, Larme and Pugh detail health professionals' perceived barriers to providing evidence-based care [85]. Physicians reported that contextual factors such as time constraints, established referral relationships, low patient awareness and motivation, and inadequate reimbursement —particularly for preventive care practices—have a larger impact on failure to reach evidence-based goals than lack of clinical knowledge. Innovative disease management systems must take these barriers into account if they are to improve care delivery.

Computer informatics systems have the ability to collect, analyze, and present clinical information to providers in an encompassing, efficient manner and to track the overall care of a population independent of provider visits. Patient and physician input is critical to the design of these systems. Success of care depends on much more than prescribing the right medicine at the right time. Patients must be engaged in their care, agree with the plan, and adhere to medications and necessary lifestyle modifications. Computer-based systems will not help with these areas, but by increasing efficiency and quality of care, these systems may "free up" more time for the effective patient-physician relationships that form the core of good medical care.

Successful programs must address the critical role that patients play in managing their illness [65]. Innovations in

integrated systems of care must be validated in well-designed controlled trials. Ultimately, by taking a population-based approach and by integrating the many benefits that modern clinical informatics systems can provide, we can greatly improve the prevailing inefficient and ineffective approach to diabetes care.

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